



## Offshore wind energy in Europe: Experiences and challenges

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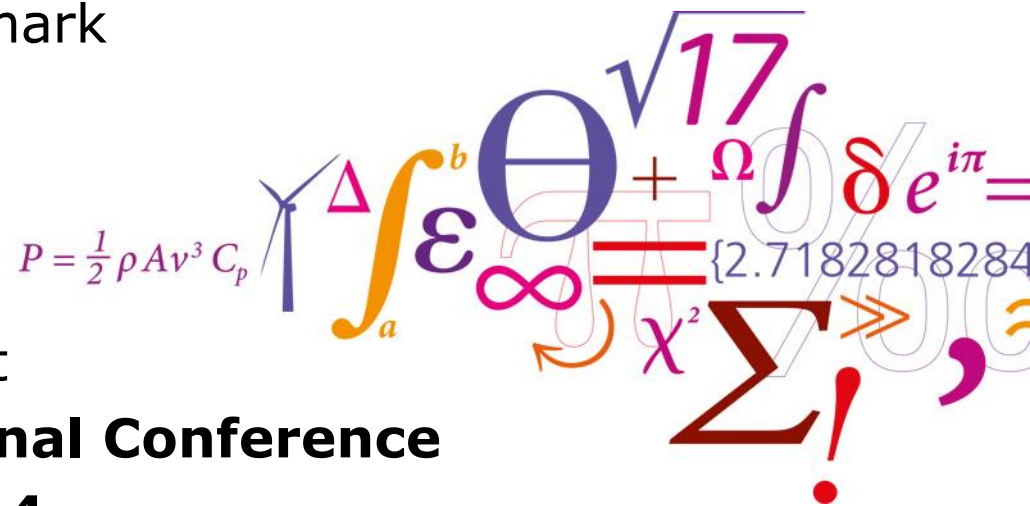
# Offshore wind energy in Europe: Experiences and challenges

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Denmark



Presentation 30 July 2014 at

**Grand RE2014 International Conference**

**July 27<sup>th</sup> – August 1<sup>st</sup> 2014**

DTU Wind Energy

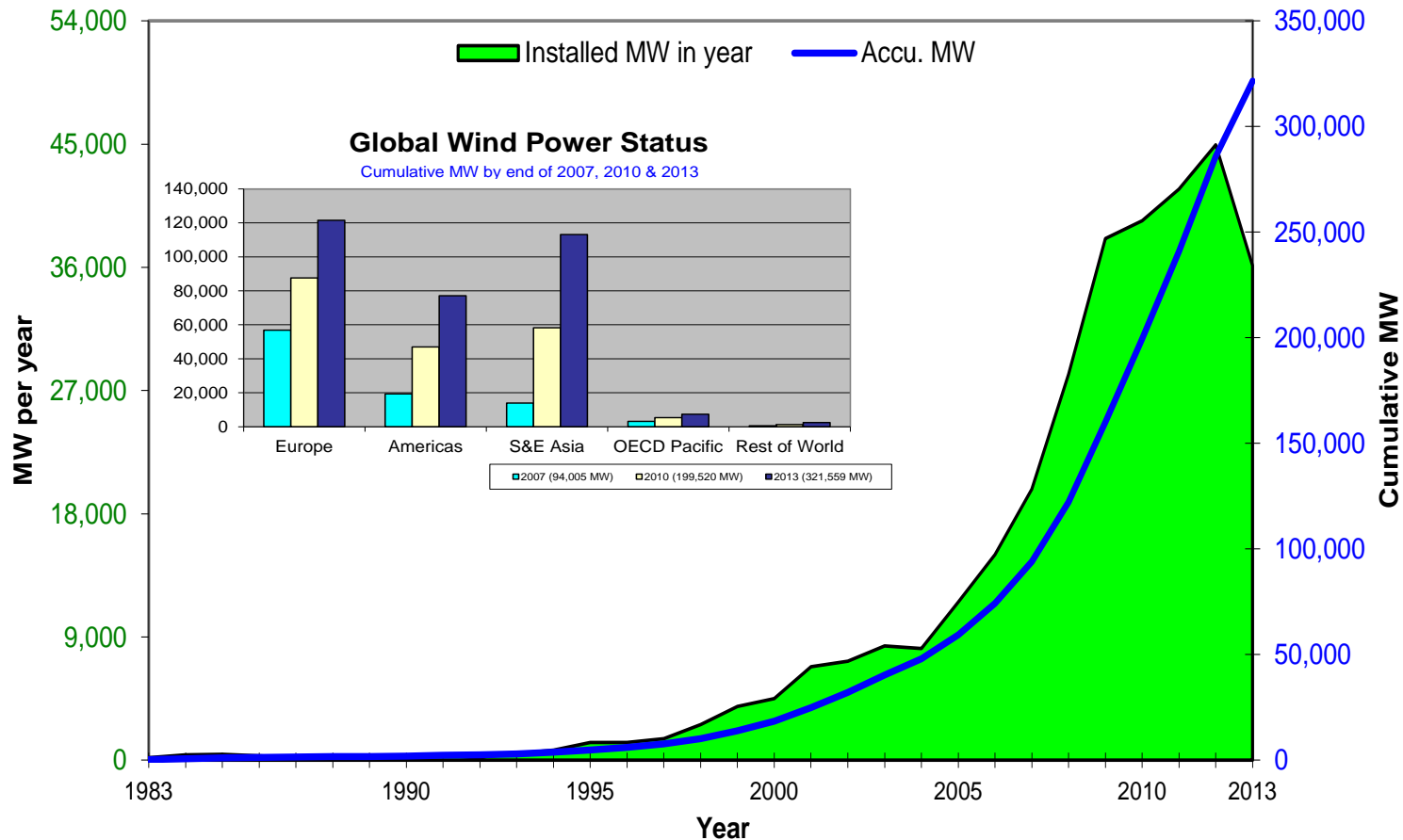
Department of Wind Energy

# Outline

- Global and European development of wind energy
- Offshore wind energy in Europe
- The cost challenge
- International cooperation
- Research
- Technology development
- Validation and testing
- Standards and certification
- Concluding remarks

# Global development of wind energy

## Installed Wind Power in the World - Annual and Cumulative -



Source: BTM Consult - A Part of Navigant - March 2014

# Penetration Rate of Wind Power in Select Countries

Region	Country	Cumulative installation - end 2013 (MW)	Penetration rate %
Europe	Denmark	4747	33.20
	Portugal	4557	27.00
	Spain	22637	20.90
	Germany	34468	11.70
	The UK	10946	7.70
	Sweden	4474	7.00
	The Netherlands	2714	4.77
	Italy	8448	4.70
	France	8128	3.10
North America	The US	61292	4.13
	Canada	7813	3.00
Asia-Pacific	China	91460	2.60
	Australia	3489	2.40
	New Zealand	603	5.00

## Penetration 2013:

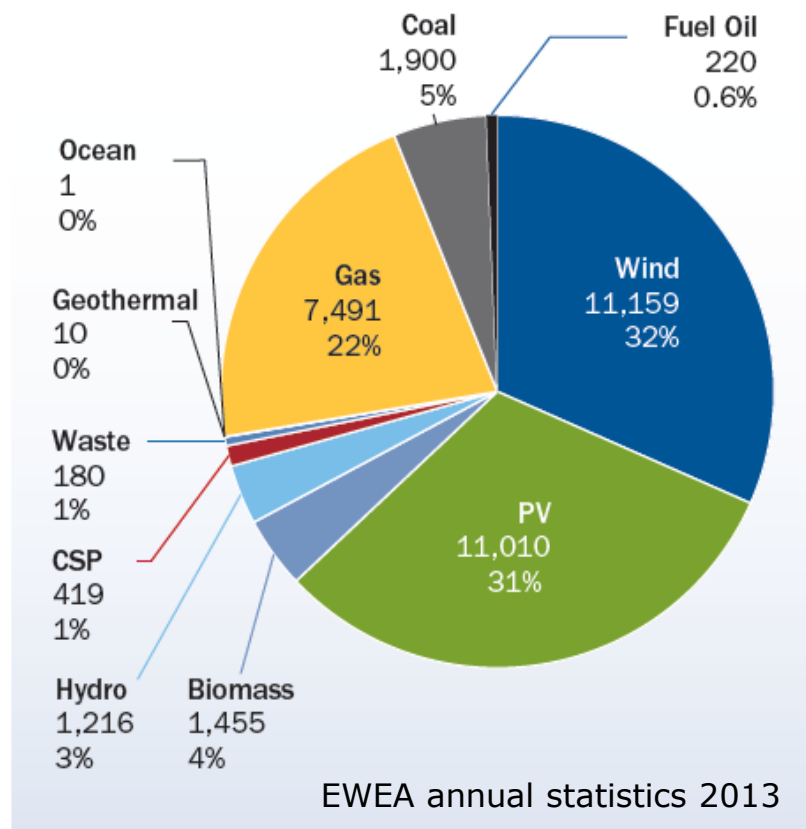
Global 2,9 %

Europe 8%

Source: BTM Consult - A Part of Navigant - March 2014

# Status 2013 in Europe

FIGURE 1.2: SHARE OF NEW POWER CAPACITY INSTALLATIONS IN EU, TOTAL 35,181 MW

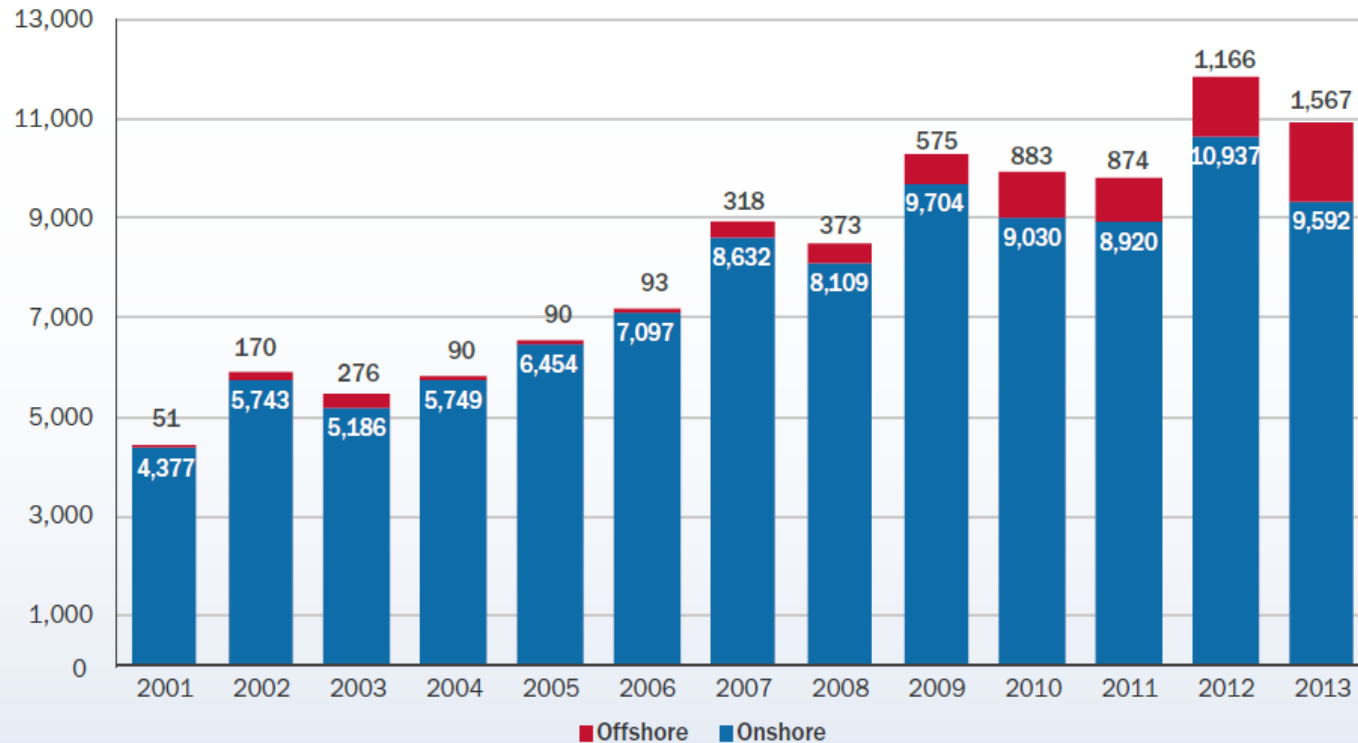


11,159 MW of wind power capacity (worth between €13 bn and €18 bn) was installed in the EU-28 during 2013, a decrease of 8% compared to 2012.

The EU power sector continues its move away from fuel oil and coal continuing to decommission more than it installs.

The wind power capacity installed by the end of 2013 would, in a normal wind year, produce 257 TWh of electricity, enough to cover 8% of the EU's electricity consumption - up from 7% 2013.

# Annual onshore and offshore installations in Europe (MW)



14 %

EWEA annual statistics 2013

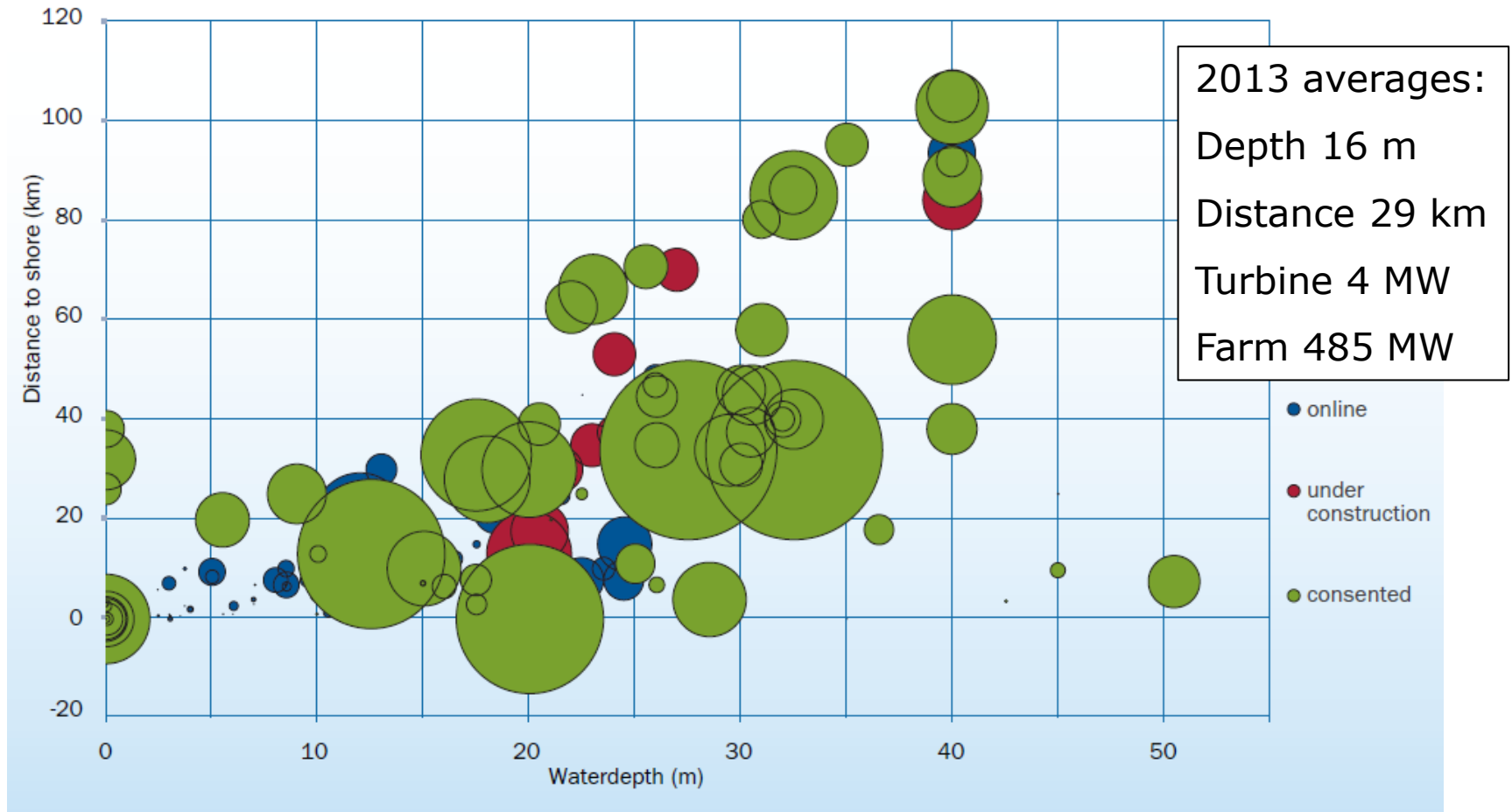
117.3 GW of installed wind energy capacity in the EU:  
110.7 GW onshore and 6.6 GW offshore.

# Cumulative offshore capacity end of 2013

- 2,080 turbines are now installed and grid connected, making a cumulative total of 6,562 MW, in 69 wind farms in eleven European countries.
- This new total of 6,562 MW of offshore wind power is enough to provide 0.7% of the EU's electricity.
- 75% of substructures are monopiles, 12% gravity, jackets 5%, tripods 5%, and tripiles 2%.
- There are also two full-scale grid-connected floating turbines, and two down-scaled prototypes.
- 418 offshore turbines came online in 2013 in Europe, making a record 1,567 Megawatts (MW) of new capacity.

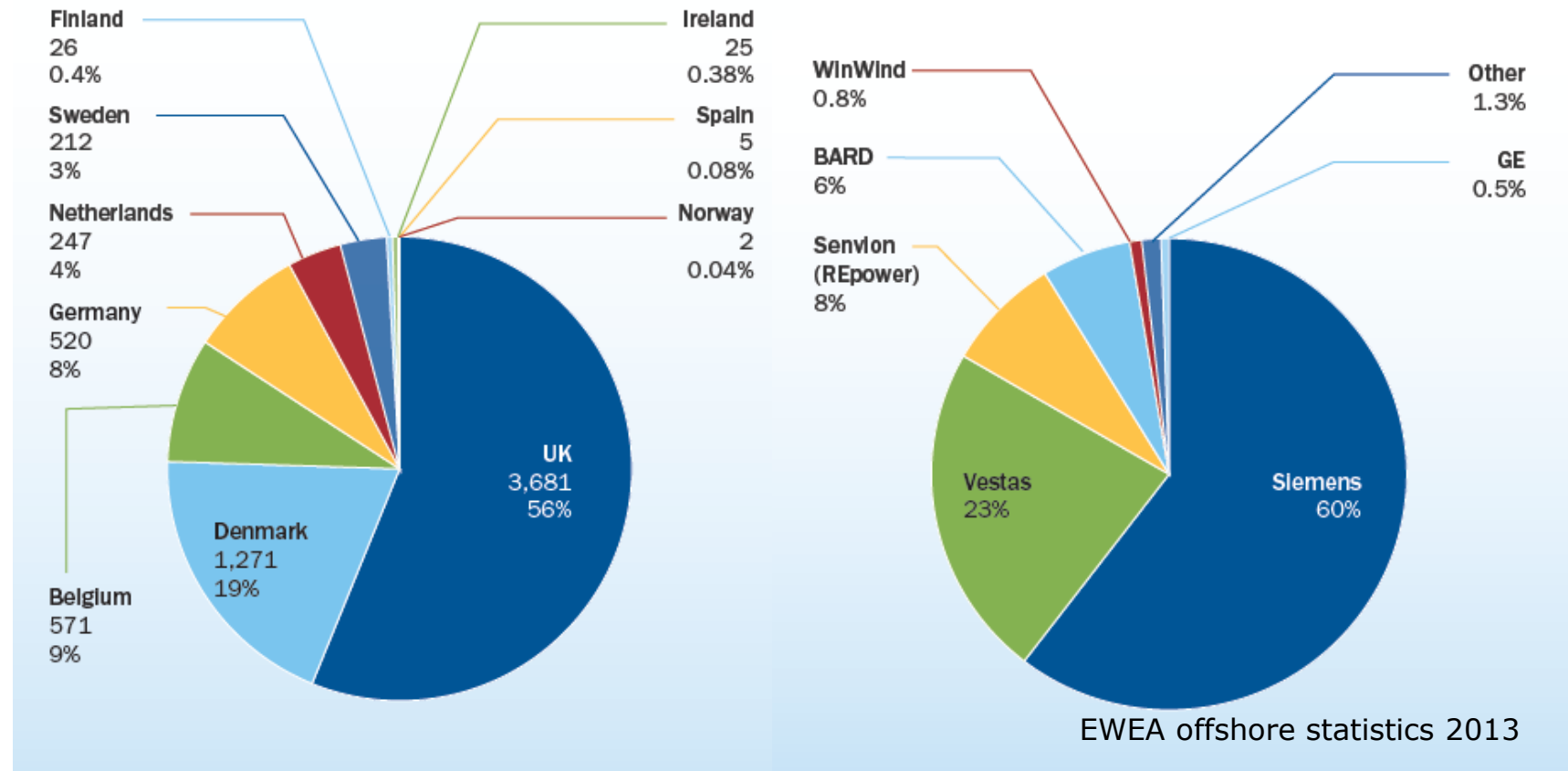


# Water depth and distance to shore

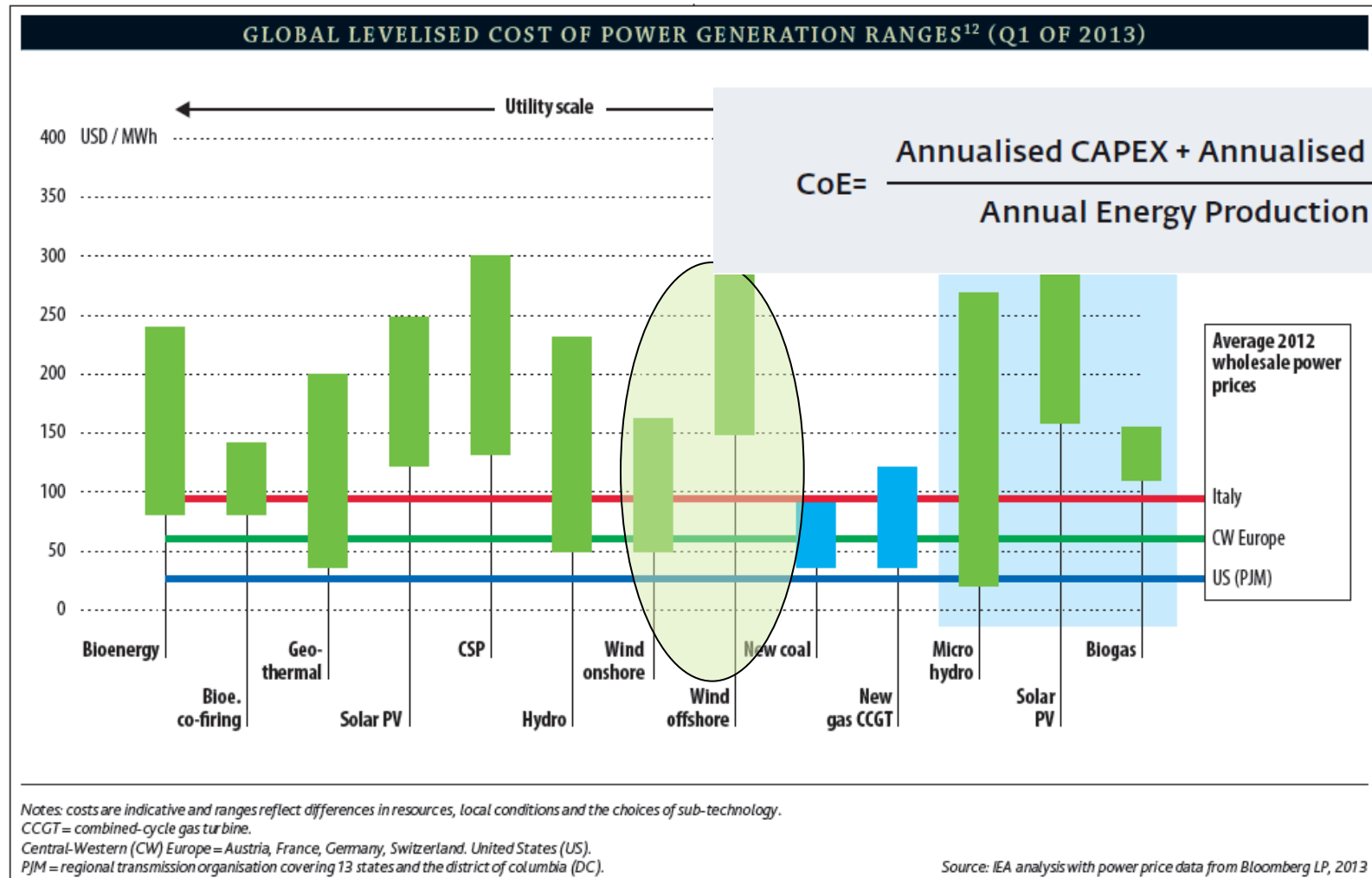


EWEA offshore statistics 2013

# Cumulative installed capacity (MW), by country and manufacturer, 2013



# The Cost Challenge



## **How to meet the cost challenge**

- International cooperation
- Research
- Technology development
- Validation and testing
- Standards and certification

# R&D cooperation in Europe

- Technology Platform for Wind energy (TPWind)

- SRA
- EWI

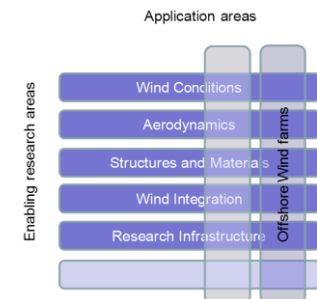


- European Energy Research Alliance (EERA)

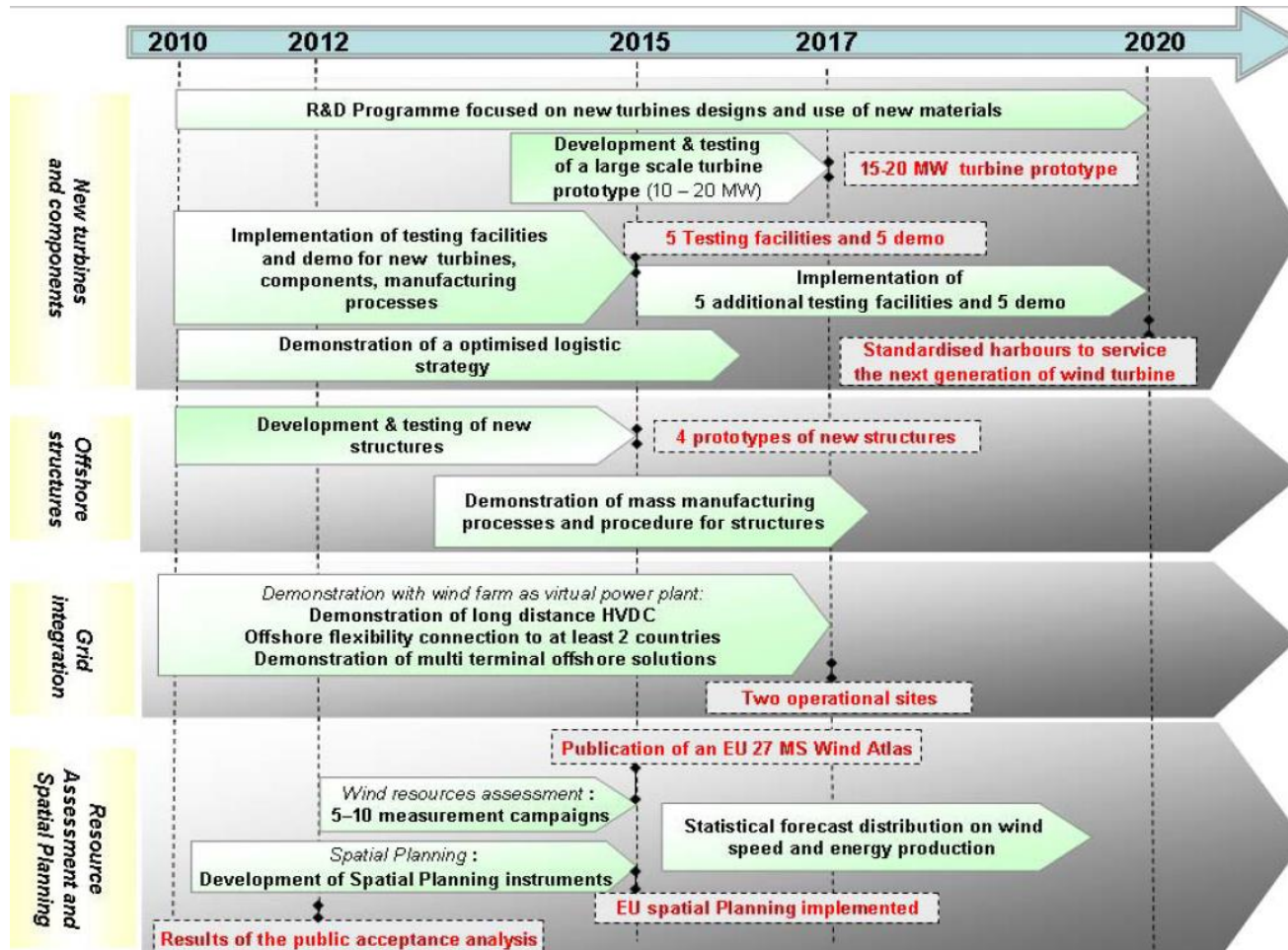
- Joint Programme for wind energy



- European Academy for Wind Energy (EAWE)
- European Wind Energy Master
- (IEA Wind R&D)
- ....



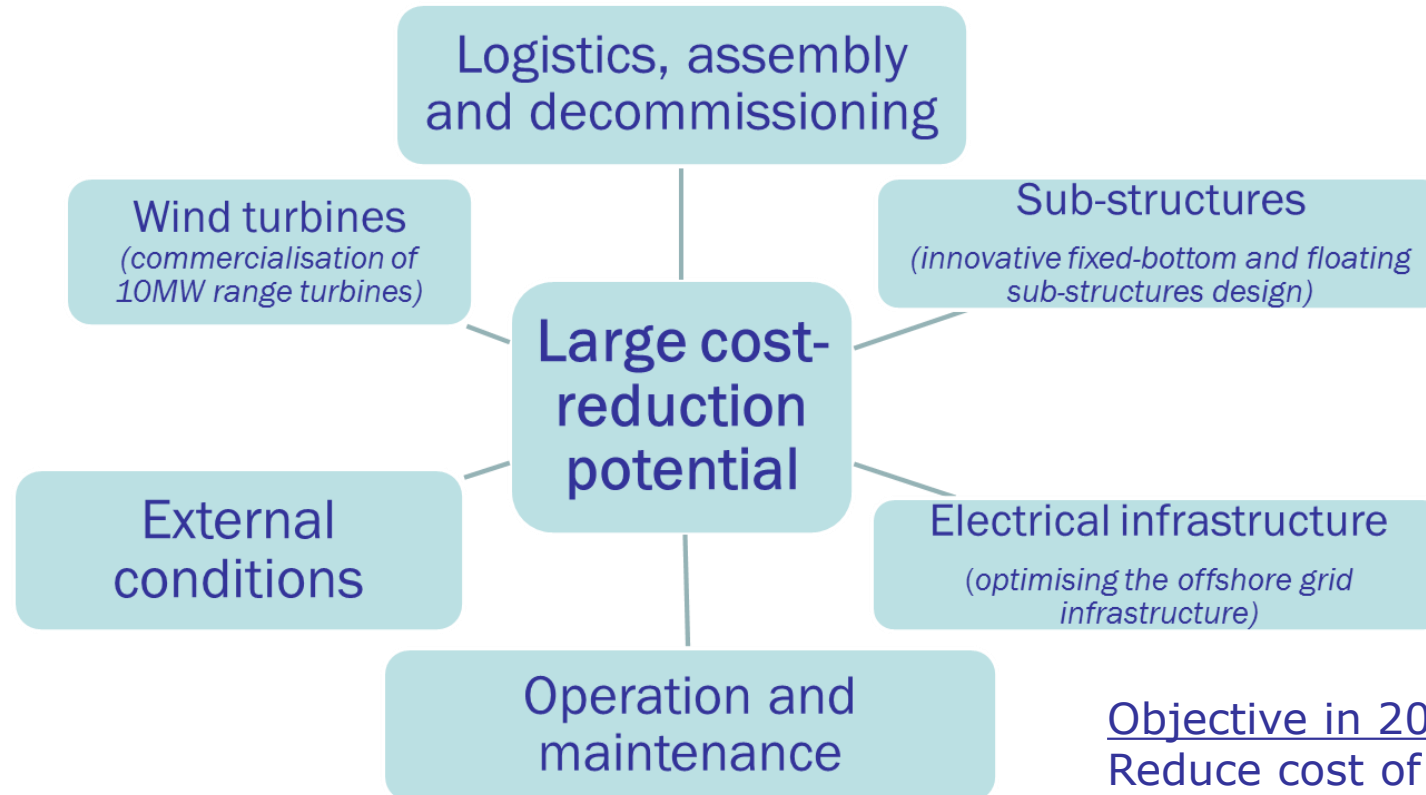
# EC SET-plan – Technology Roadmap



Roadmap for the implementation of the SET Plan and the RES Directive:

- Large scale integration and
- An accelerated offshore wind energy deployment, including
- Very large offshore wind turbines.

# TPWind Strategic Research Agenda Offshore Technology



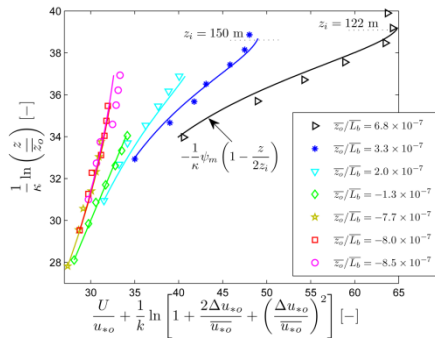
## Objective in 2014:

Reduce cost of generating power from wind power plants in 2030 by:

- 20% onshore *and*
- 50% offshore



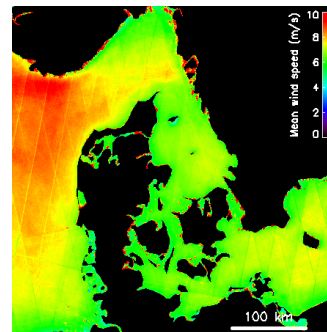
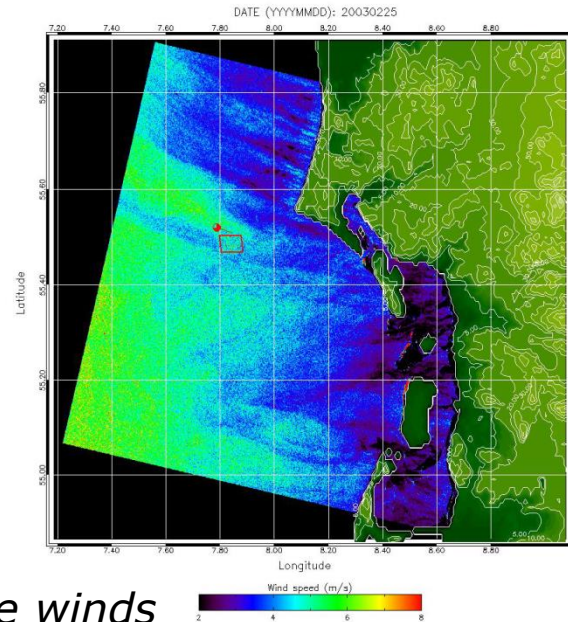
# Offshore Wind Conditions



*Lidar wind data and model from Horn's Reef offshore*



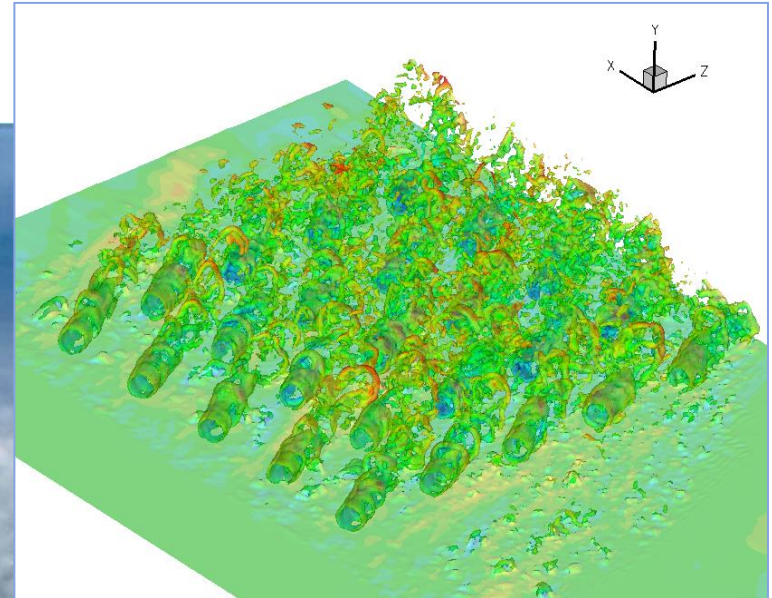
*Satellite winds showing the wake at Horn Reef wind farm. Mean wind speed map using satellite Envisat ASAR.*



- Ocean winds
- Lidar observations and modelling
- Wind resource mapping using satellite data
- Mesoscale modelling
- Meteorological mast observations
- Wind farms shadow effect
- Satellite observations

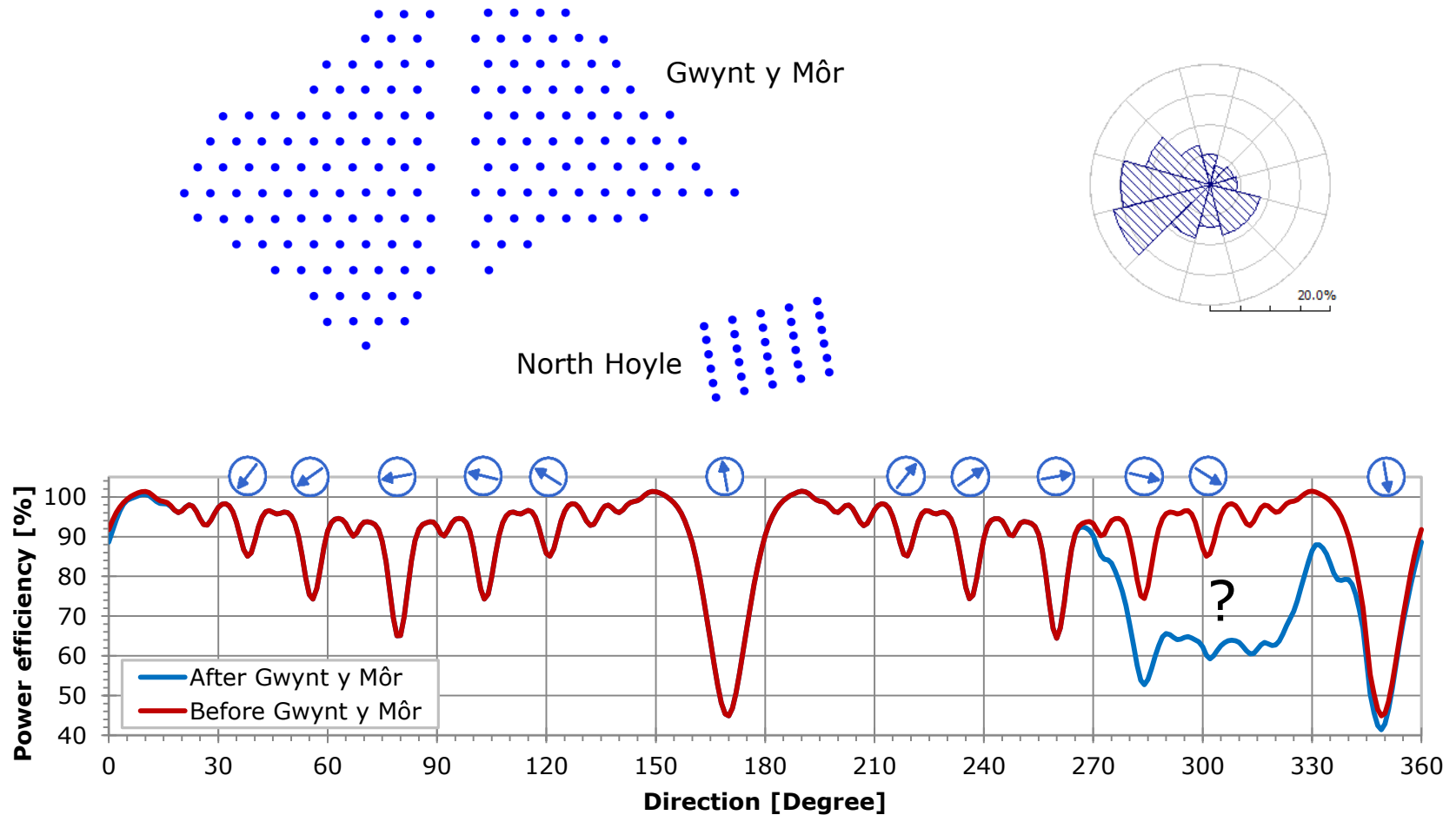


# Wake effects – a complex flow essential for performance and loads



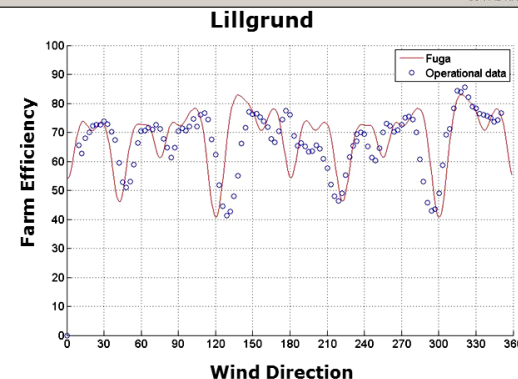
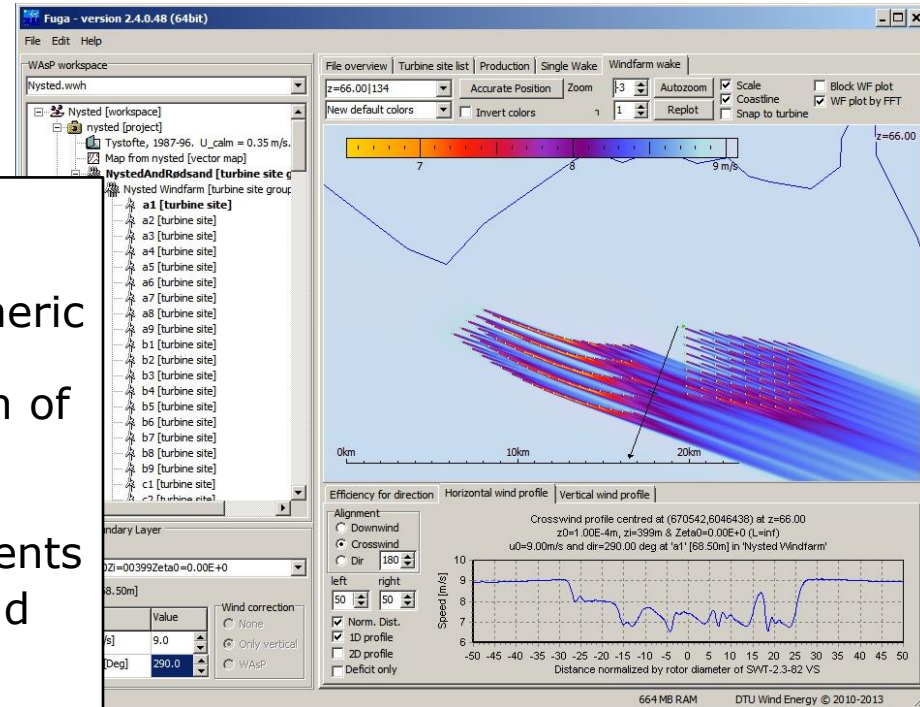
Vorticity shed from 5x5 turbines in a farm computed by actuator disk method

# Wind farm efficiency of North Hoyle @ $10 \text{ ms}^{-1}$



# Fuga – a new wake model

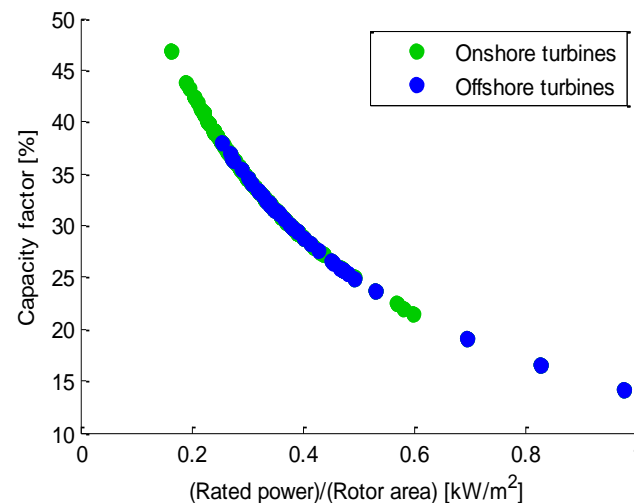
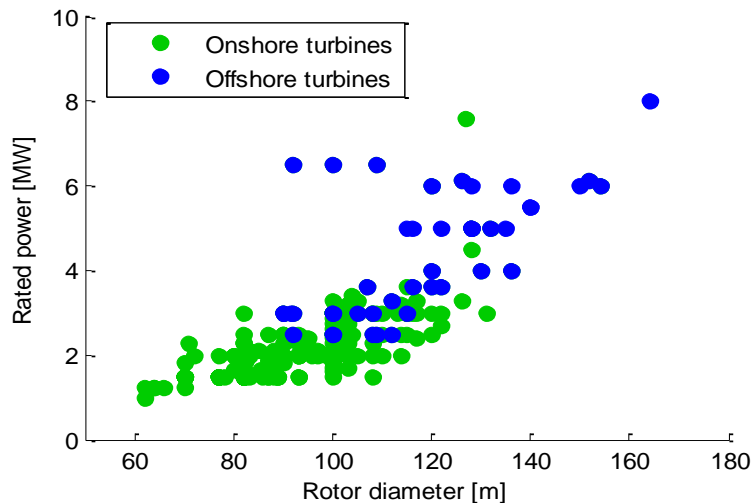
- Solves linearized RANS equations
- Latest version incorporates: atmospheric stability, meandering, effects of non-stationarity and spatial de-correlation of the flow field.
- No computational grid, no numerical diffusion, no spurious pressure gradients
- Integration with WAsP: import of wind climate and turbine data.
- Fast, mixed-spectral solver:
  - $10^6$  times faster than conventional RANS!
  - $10^8$  to  $10^{10}$  times faster than LES!



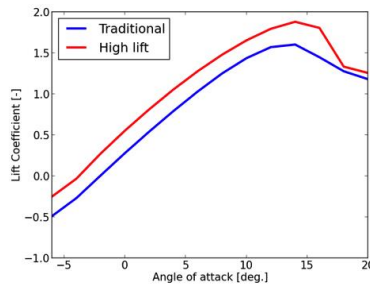
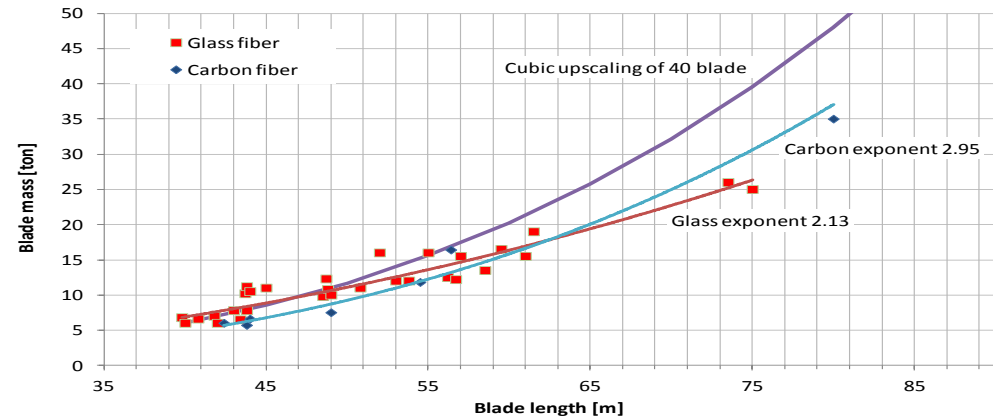
# Upscaling – larger turbines, larger rotors

Year	2011	2012	2013
Total MW supplied	40,495	43,134	37,478
Product (Size range)	% of total MW		
"Small WTGs" <750 kW	0.6%	0.1%	0.1%
"One-MW " 750-1499 kW	6.6%	3.5%	2.8%
"Mainstream" 1500-2500 kW	85.7%	83.5%	79.6%
"Multi-MW Class" >2500 kW	7.2%	12.8%	17.5%
<b>Total</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>

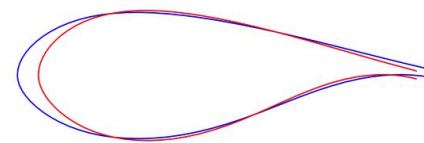
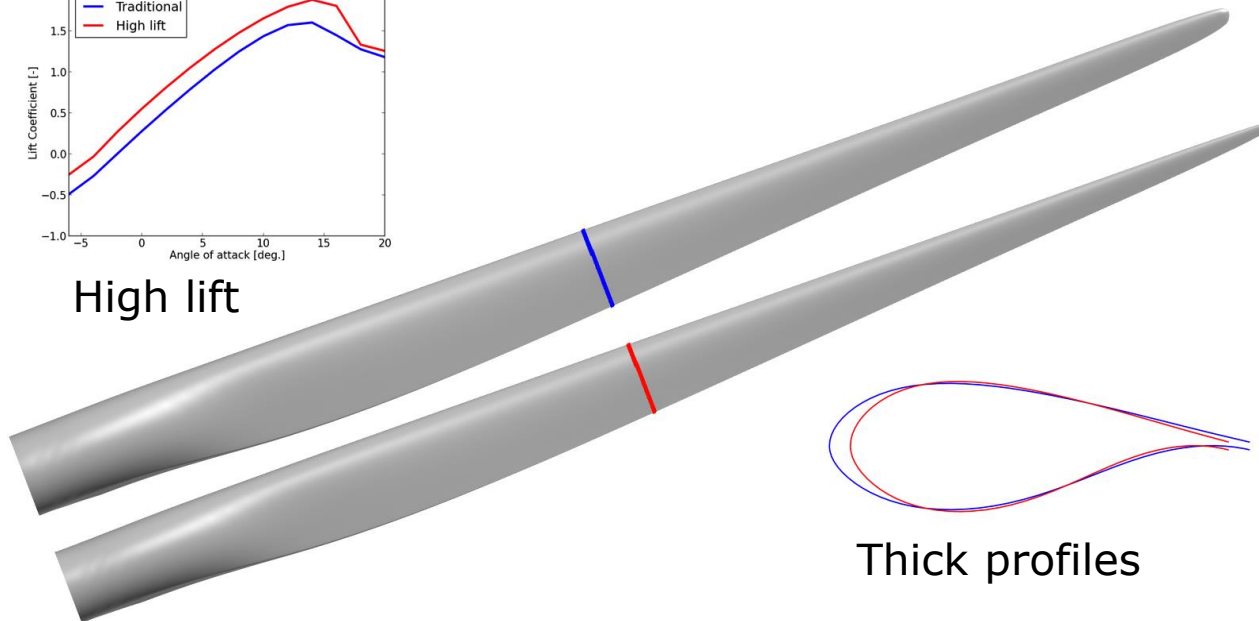
Source: BTM Consult - A Part of Navigant - March 2014



# Larger rotors – slender blades to beat the cubic-law



High lift



Thick profiles

**Advances in:**

- Aerodynamics
- Stability
- Dynamics
- Structures
- Materials
- Validation



# Offshore in deep water

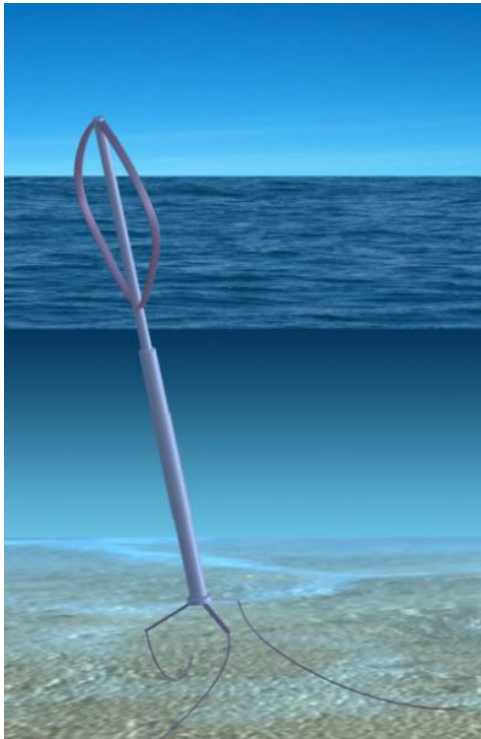


*Combined wind and wave energy – Poseidon*

*Concept Hywind. Source: Norwegian Hydro and Solberg production*

**Grand RE2014 International Conference July 27<sup>th</sup> – August 1<sup>st</sup> 2014**

# DEEPWIND – a floating VAWT



VAWT Simulation suite finished

**Achievement:** Blade mass reduce significantly from about 800 kg/m to 230 kg/m

Pulltrusion process simulation

Generator + bearing design program

Control ready

Demonstrator tests finished

# The Walney Offshore Wind (WOW) Project



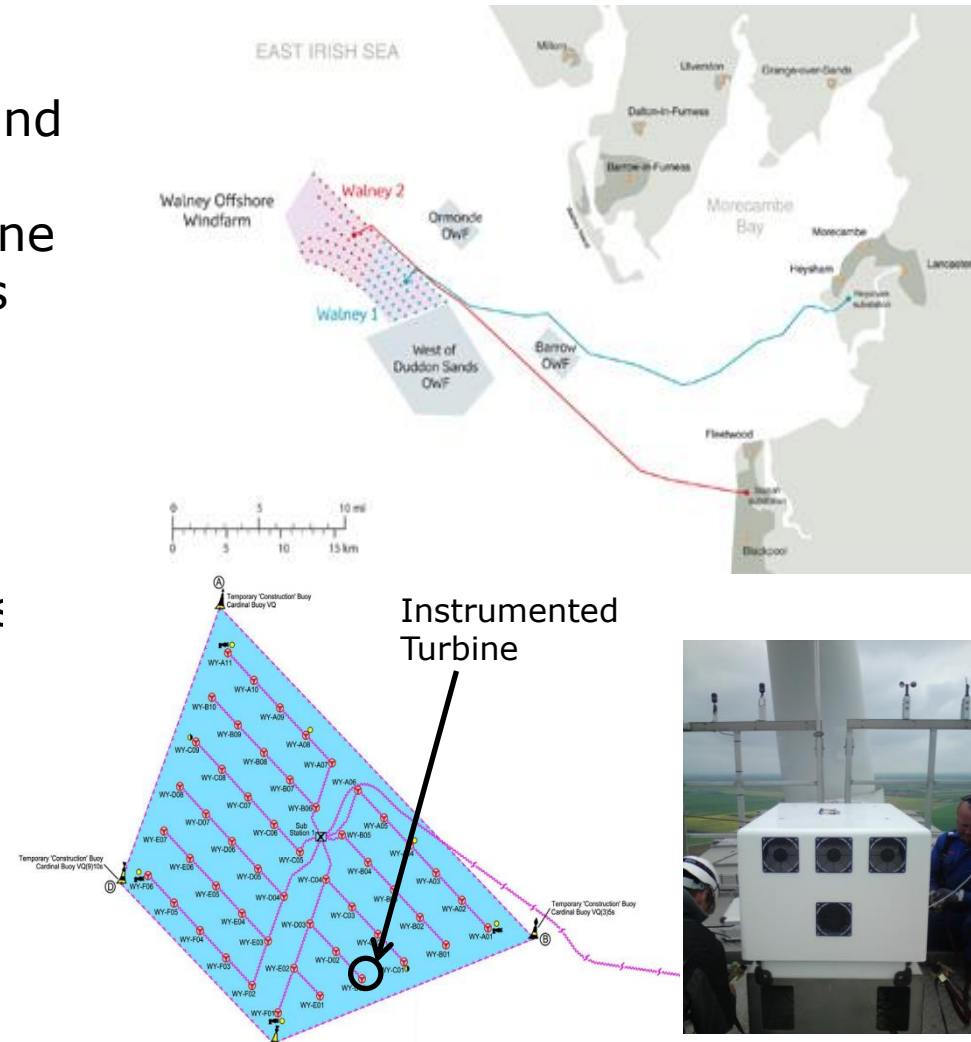
Comprehensive loads validation on a state of the art 3.6MW wind turbine in cooperation with Siemens and DONG energy

## Key Measurements

- Nacelle mounted LIDAR for wind measurements
- Wave sonar and Buoy at turbine
- Accelerometers, strain gauges on
- Blade root, drive train, tower and foundation

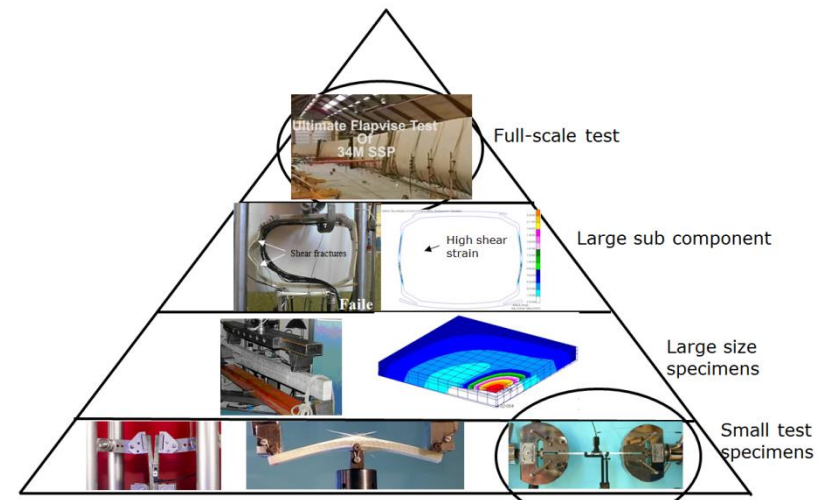
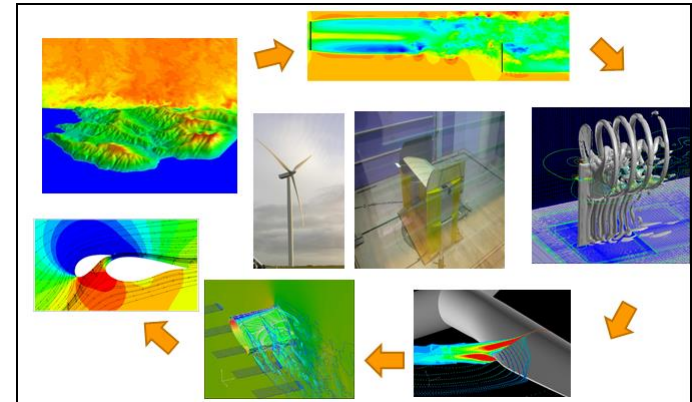
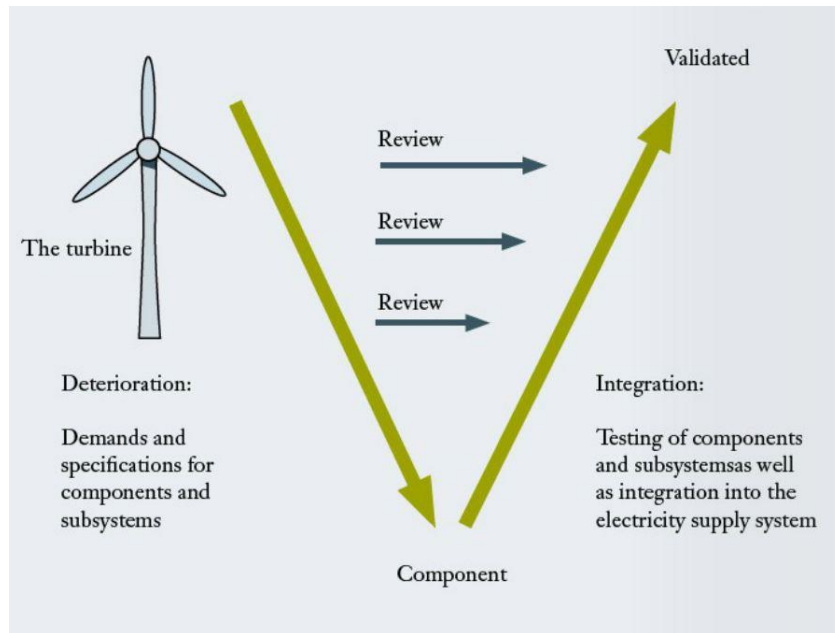
## Scientific Objectives

- Validation of the dependencies of design loads
- Prediction of turbine net damping
- Advanced wind/wave correlation studies
- Wake effects on loads



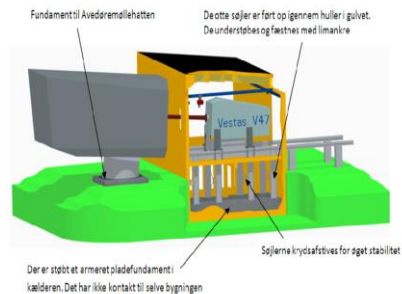
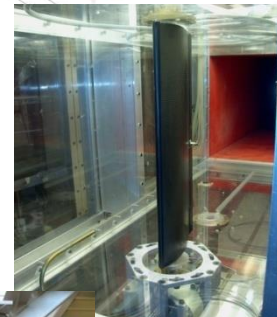
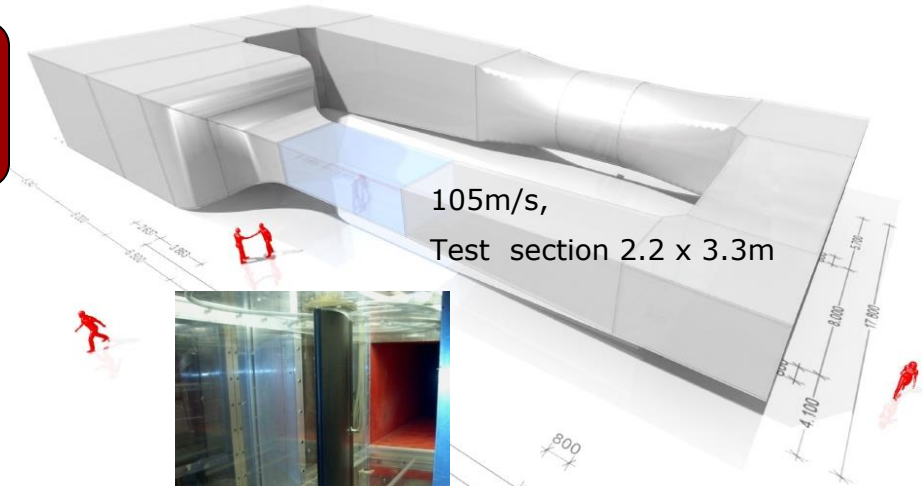
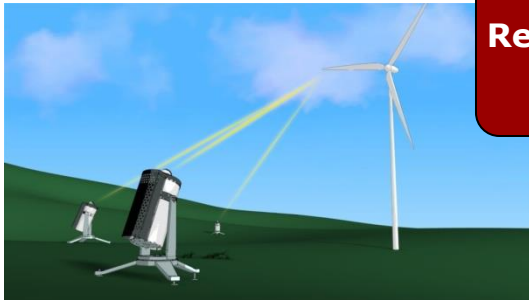


# Validation – Products and research



# Experiments, Validation and Test

**Research and test facilities**



# The Testcenter in Østerild

## Wind turbine testing:

- Tests acc. to international standards (IEC)
- Development tests

## Research:

- Meteorology (Wind)
- Turbine technology
- Grid integration





# International wind turbine standards - IEC

## a) Safety & functional requirements



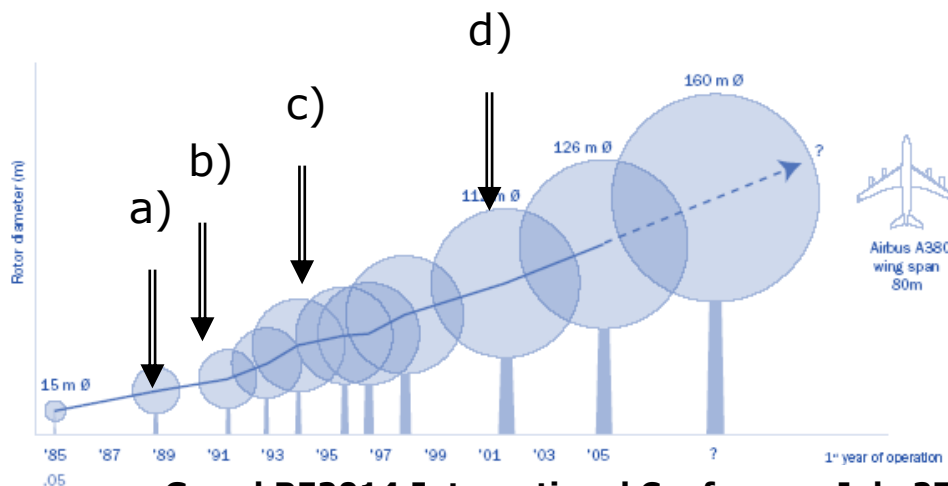
## b) Test methods



## c) Certification procedures



## d) Interfaces & Component



## IEC TC88: IEC 61400 series:

IEC 61400-1 Design requirements

IEC 61400-2 Small wind turbines

IEC 61400-3 Design requirements for offshore wind turbines

IEC 61400-4 Gears for wind turbines

IEC 61400-(5) Wind Turbine Rotor Blades

IEC 61400-11, Acoustic noise measurement techniques

IEC 61400-12-1 Power performance measurements

IEC 61400-13 Measurement of mechanical loads

IEC 61400-14 Declaration of sound power level and tonality

IEC 61400-21 Measurement of power quality characteristics

IEC 61400-22 Conformity Testing and Certification of wind turbines

IEC 61400-23 TR Full scale structural blade testing

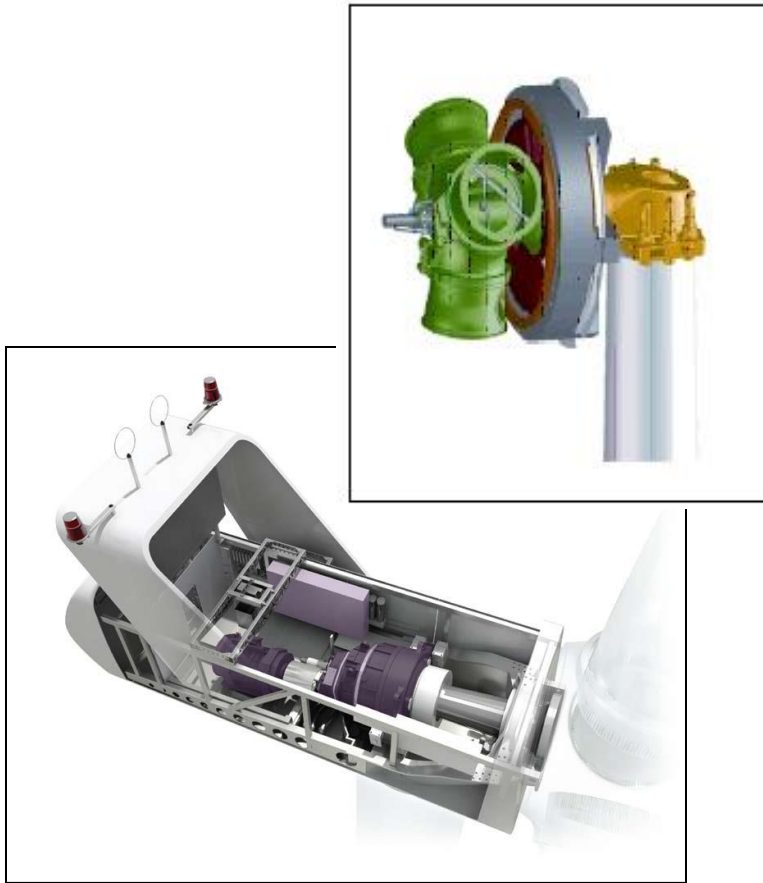
IEC 61400-24 TR Lightning protection

IEC 61400-25-(1-6) Communication

IEC 61400-26 TS Availability

IEC 61400-27 Electrical simulation models for wind power generation

# Offshore wind turbine installation – a series-produced machine or a custom built structure



Wind turbine generator system



~ Wind turbine structure

# Revision of **IEC 61400-1**

## **Wind turbines - Part 1: Design Requirements**

The revision scope shall include but not be limited to the following issues:

- External conditions:
- Cold climate conditions
- Structural Design
- Assessment of a wind turbine for site-specific conditions

### Status

- 11 meetings held
- Committee draft to be submitted to IEC TC88 Sept. 2014

### Sub-committees:

1. Assessment of site conditions (Thomas Hahm)
2. Wake effects (Graeme McCann)
3. Load cases/load calculation requirements (Enrique Gomez de Las Heras)
4. Safety factors (John Dalsgaard Sørensen)
5. Medium Wind Turbines (Julian Martin)
6. Cold Climate (Ville Lehtomäki)
7. Electrical systems (Tim Zgonena)
8. Tropical conditions (Hiroshi Imamura)

# IEC 61400-1- Basic parameters for wind turbine classes

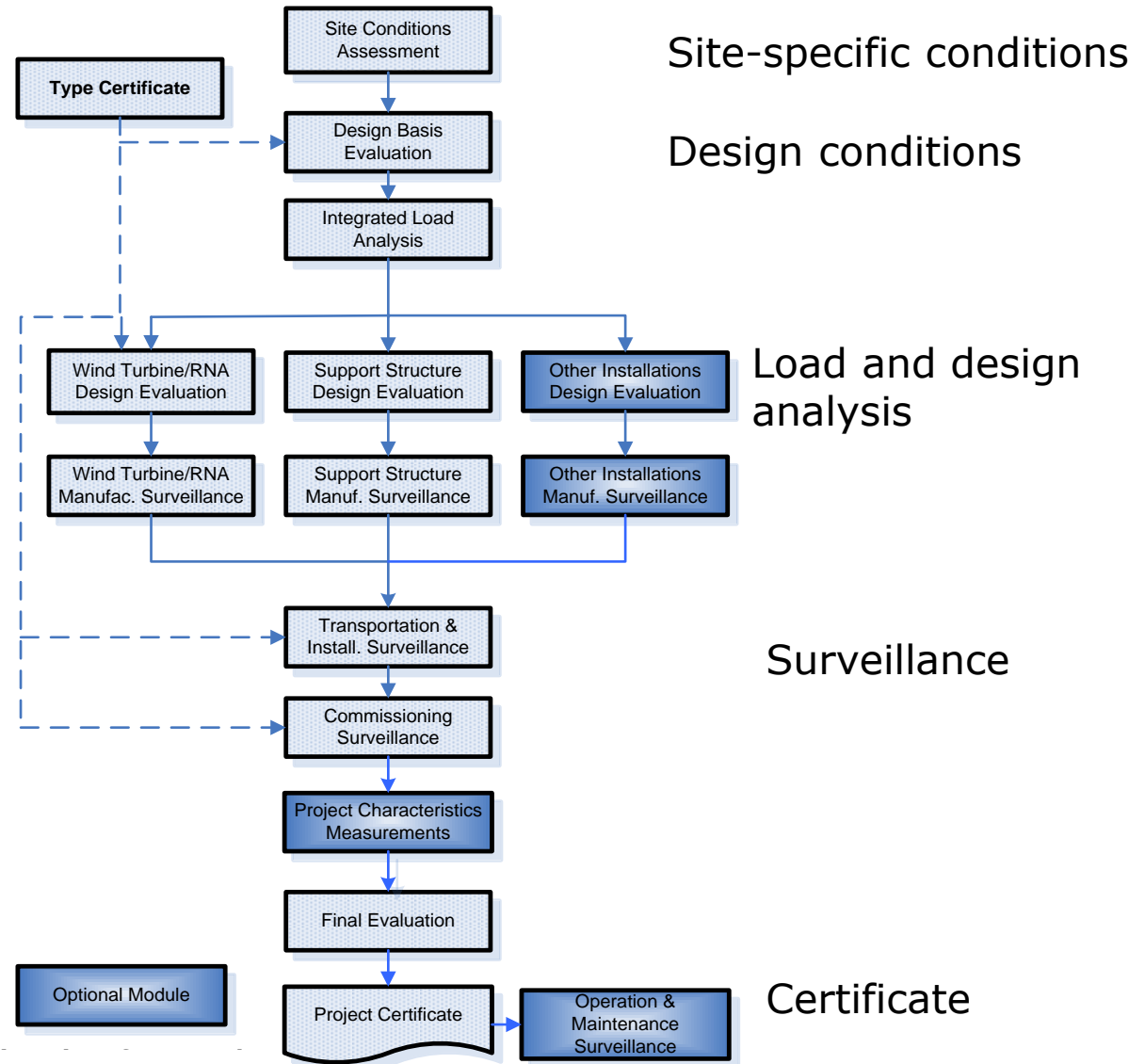
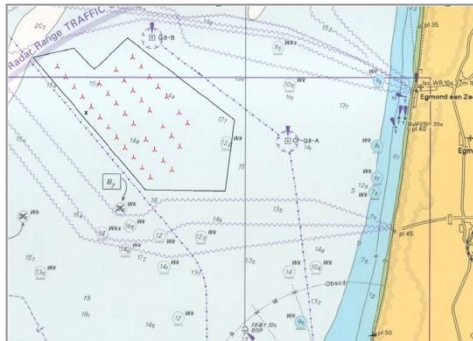
Wind turbine class	I	II	III	S
$V_{ref}$ (m/s)	50	42,5	37,5	Values specified by the designer
$V_{ave}$ (m/s)	10	8,5	7,5	
$V_{ref,T}$ (m/s)	57			
A+ $I_{ref}$ (-)	0,18			
A $I_{ref}$ (-)	0,16			
B $I_{ref}$ (-)	0,14			
C $I_{ref}$ (-)	0,12			

The load partial safety factors for DLC 6.1 and DLC 6.2 are derived by assuming that the coefficient of variation of the annual maximum wind speed, COV, is smaller than 15%. If COV is larger than 15%, they shall be increased linearly by a factor  $\eta$  from 1.0 at COV = 15% to 1.15 at COV = 30%.

# Project Certification

(IEC 61400-22)

"Fit-for-Purpose"





## Concluding remarks

- Expansion of wind energy installations has slowed down but is still going strong
- Wind energy plays a major role in Europe's energy mix
- Offshore wind energy expands but mostly in Europe
- But, offshore wind energy has a cost challenge
- The challenges must be met by
  - International cooperation
  - Research
  - Technology development
  - Validation and testing
  - Standards and certification

**Thank you for your attention**

